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SONAR TRANSDUCER RELIABILITY IMPROVEMENT PROGRAM FY80.(U)  
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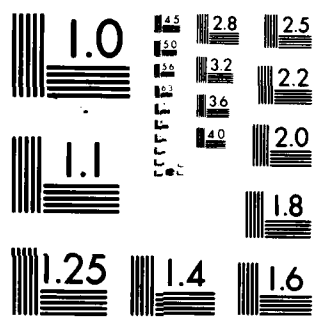
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NRL Memorandum Report 4166

**Sonar Transducer Reliability  
Improvement Program FY 80**

**First Quarter Progress**

**R. W. TIMME**

*Materials Section  
Transducer Branch*

*Underwater Sound Reference Detachment  
P.O. Box 8337, Orlando, FL 32856*

January 1, 1980

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Progress accomplished during the first quarter of FY80 in the Sonar Transducer Reliability Improvement Program is reported. Each of the six major task areas is discussed in some detail. The most significant aspects include determinations that high purity SF <sub>6</sub> for use in transducers is an unnecessary expense, a cork-silicone composition is a better pressure release material than the commonly used cork-neoprene composition, and that unshielded cable cannot be used in compression-type hull penetrators. Several new starts are identified.		

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Sonar Transducer Reliability Improvement Program  
NRL Problem 82-0584-0  
FY80 First Quarter Progress Report

1. INTRODUCTION

1.1. PROGRAM OVERVIEW

The general objective of this program is to perform relevant engineering development which addresses the operational requirements for fleet transducers for active sonar, passive sonar, surveillance, counter-measures and deception devices, navigation, and acoustic communications. The approach is to develop, test, and evaluate improved transducer design, materials, components, and piece parts that will meet specified requirements in the operational environment during the entire useful life of the transducer. Standards will be prepared to ensure that results obtained during preliminary testing will be obtained consistently in production. This program should result in improved performance and reliability and reduced costs through better utilization and a more comprehensive characterization of materials and design data. The program goals are as follows:

- Reduction in transducer replacement costs
  - Goal - less than 9% of population replaced each year with no automatic replacements at overhaul
  - Threshold - less than 18% of population replaced each year
- Improvement in transducer reliability
  - Goal - less than 1% of population failures each year
  - Threshold - less than 3% of population failures each year
- Improvement in transducer receiving sensitivity
  - Goal - less than  $\pm 1$  dB variation from the specified value over operational frequency band
  - Threshold - less than  $\pm 2$  dB variation from the specified value over operational frequency band

The Sonar Transducer Reliability Improvement Program (STRIP) is a part of Program Element 64503N. Major task areas with specific objectives to achieve the program goals have been described in the Program Plan and include:

- Task Area A. Encapsulation Methods
- Task Area B. High Voltage Engineering
- Task Area C. Cables and Connectors
- Task Area D. Transducer Material Standards
- Task Area E. Environmental Test Methods
- Task Area F. Transducer Tests and Evaluation

The FY80 Program Plan for STRIP has been funded at the \$495 K level. The specific tasks and their Principal Investigators for FY80 are listed below:

	<u>TASK</u>	<u>PRINCIPAL</u>	<u>INVESTIGATOR</u>
A-1	Fluids and Specifications	NRL	C.M. Thompson
B-1	Corona Abatement	NRL	L.P. Browder
C-1	Handbook for Harness Design	Contractor	
C-2	Standard for O-ring Installation	APL/University of Washington	C.J. Sandwith
C-3	Cable and Connectors	TRI	D.E. Glowe
D-1	Alternative Materials - Plastics	NWSC	D.E. Moore
D-2	Pressure Release Materials	NUSC	C.L. LeBlanc
E-1	CUALT	NOSC	J. Wong
E-2	ALT Verification	NWSC	D.E. Moore
F-1	Failure Modes due to Water	TRI	D. Barrett
F-2	Shock Hardened Pressure Release	Westinghouse	C.J. Wilson
F-3	Reliability and Life Prediction Specification	Contractor	
F-4	Engineering Documentation	NRL	R.W. Timme

## 1.2. SUMMARY OF PROGRESS

During the first quarter of FY80, efforts in the various tasks of STRIP have resulted in progress toward the program goals as summarized below:

- The physical parameters of gas pressure and air or water vapor contamination of sulfur hexafluoride (SF<sub>6</sub>) gas have a minimal effect on the lifetime function for high-voltage drive of PZT ceramic. Therefore, strict



specifications in any procurement contract for gas-filled transducers calling for high purity SF<sub>6</sub> will result in an unnecessary expense. See Section 3.3.2.

- The most commonly used pressure release material is a cork-neoprene composite known as DC-100. Tests have shown that a cork-silicone composition, LC-800, is not only initially superior to the DC-100, but is many times more resistant to degradation by oil soaking. See Section 8.3.2.
- An investigation of the strength of shielded vs unshielded cable shows continual movement of the unshielded cable through a packing gland from pressure cycling. Also, initial results from comparative testing of neoprene vs polyurethane molded Portsmouth connectors shows failure of the polyurethane bond but no neoprene bond failures. See Section 6.3.1.
- Composite unit accelerated life testing has been performed on DT-605 hydrophones to simulate a one year life service. The hydrophones are still completely within specification. No design problems have been found; testing continues. See Section 9.3.
- New starts for FY80 have been made in Tasks C-2, D-1, E-2, F-1, and F-2. New efforts will be made in Tasks C-1 and F-3 when contract procedures are completed.

### 1.3. PLANS

The annual review for the STRIP will be held on 11 and 12 March 1980, starting at 0830, in the Conference Room in Building 226 at the Naval Research Laboratory in Washington, DC. The objectives of the meeting are:

- To inform the NAVSEA managers, the laboratory sonar engineers, and the TRF engineers of R&D being directed toward their problems.
- To inform the present and potential STRIP principal investigators of the transducer problems facing the fleet, and
- To initiate planning for the FY81 STRIP.

NAVSEA has issued time guidelines for preparing work planning summaries for FY81. The date of 12 May has been suggested as the deadline for firm plans for FY81. Therefore, an invitation for proposals of work to be included in STRIP FY81 will be extended at the annual review on 12 March 1980. The deadline for proposals will be 18 April 1980. It is planned that the FY81 STRIP plan will be ready by 12 May 1980.

#### 1.4. REPORT ORGANIZATION

The remaining sections of this quarterly report will discuss the objectives, progress, and plans for the specific tasks included in the STRIP.

## 2. TASK A-1 - TRANSDUCER FLUIDS AND SPECIFICATIONS

*C. M. Thompson - NRL-USRD*

### 2.1. BACKGROUND

A material to be used for filling a sonar transducer must meet a wide variety of specifications. The requirements imposed by the electrical nature of the device include high resistivity, high dielectric constant, as well as resistance to corona and arc discharges. The water environment of the transducer necessitates low water solubility and other attractive solution properties. In addition, the fluid must maintain its electrical and other properties in the presence of any water which permeates the covering. The acoustic requirements are a close acoustic impedance match with sea water and resistance to cavitation at high-drive levels. Other obvious properties include compatibility with other components, stability to degradation, suitable surface tension, and viscosity.

With such a wide variety of requirements, it is not surprising that compromises have to be made. The most commonly used fluid for many years has been castor oil. This use is in spite of its high viscosity. Each of the fluids proposed, so far, as a replacement has serious drawbacks. Silicone oils tend to creep onto and wet all of the surfaces of the transducer. This greatly complicates bonding the components together. Polyalkylene glycol (PAG) has the disadvantages of a high water solubility and low electrical resistivity. The various hydrocarbon liquids have too low an acoustic impedance and are frequently incompatible with the various plastics and rubbers in the transducer. Further research is necessary to find and qualify fill-fluids which represent the best match to all the requirements imposed upon it.

### 2.2. OBJECTIVES

The objectives of this task are:

- To find plausible new transducer fill-fluids which combine the best properties. Candidates include: hydrophobic-polyethers, sterically protected esters, chlorine - or fluorine - containing hydrocarbons, and possibly aromatic hydrocarbons.
- To apply the criteria developed during the PAG and castor oil testing to the most promising candidate fluids.

## 2.3. PROGRESS

2.3.1. Measurements of density and sound speed have been performed for a variety of existing and potential transducer fluids. These measurements were carried out as part of a continuing effort to compare these materials. Density as a function of temperature was determined using carefully calibrated Cassia flasks. The sound speed as a function of temperature was determined with a NUS Corp. Model 6105 velocimeter. These results are given in Table 2.1.

FLUID	DENSITY (kg/m <sup>3</sup> at 0°C)	CHANGE WITH TEMP. (kg/m <sup>3</sup> /°C)	SOUND SPEED (m/s at 0°C)	CHANGE WITH TEMP. (m/s/°C)
Isopar L	777.48	-0.739	1342	-4.0
Isopar M	789.39	-0.725	1359	-3.9
Polyalpha-olefin (PAO)	856.43	-0.630	1532	-3.6
Transformer Oil No. 55	902.9	-0.69	1507.5	-3.73
Methyl Alkyl Silicone: GE SF1147	901.38	-0.701	1356.6	-3.29
Dimethyl Silicones: DC200 (65 cs visc)	786.22	-1.062	1049	-3.05
DC200 (50 cs visc)	980.80	-0.915		
Tricresyl Phosphate	1184.15	-0.827	1586.1	-3.50

Table 2.1 - Density and Sound Speed of Several Transducer Fluids

From this data, the magnitude of the acoustic impedance may be calculated ( $\rho \cdot c$ ) at any temperature within the measurement ranges (0-50°C).

2.3.2. Tricresyl phosphate (TCP) is an aromatic phosphate ester which has found a wide range of applications such as gasoline additive (lead scavenger), plasticizer for cellulose nitrate and synthetic plastics, hydraulic fluid, and vacuum pump oil. The readily available and obvious properties of this material suggest the possibility of its use as a transducer fluid. The handbook value for density of TCP is 1160 kg/m<sup>3</sup> at 25°C. Measurement of density as a function of temperature at USRD gave:

$$\rho(\text{kg/m}^3) = 1184.15 - 0.827 T (^\circ\text{C}). \quad (2.1)$$

Viscosity of TCP is reported to be 69 centistokes at 20°C. The water solubility limit is reported by one of the manufacturers to be 0.4% at 25°C. In a brief compatibility test performed at GD/EB, silicone rubber, butyl rubber, and "Viton" rubber (along with

Nylon and "Teflon") were barely affected and nitrile rubber was severely degraded. A series of compatibility tests are underway at USRD. Early results confirm the findings of GD/EB. Additionally, from our tests, TCP is obviously incompatible with natural and neoprene rubbers but is fairly compatible with EPDM rubbers.

The surface tension measured at USRD for TCP is 0.00155 N/m.

Sound speed of TCP was measured and is best expressed by

$$c(\text{m/s}) = 1586.1 - 3.50 T (^{\circ}\text{C}) \quad (2.2)$$

A serious potential problem for TCP is the potential for hydrolysis. Although TCP is the most resistant to hydrolysis of the phosphate esters, if hydrolysis should occur, a relatively strong acid would be produced with resulting corrosion. Experiments are underway at USRD to measure both the rate of hydrolysis of TCP and the rate of attack of the hydrolysis products on metals. Important unknown properties of TCP are cavitation level, acoustic attenuation, and low level toxicity. Some of these will be determined in further testing or from manufacturers' literature.

2.3.3. The water permeation equations are now fairly well understood [1]. The next step in the analysis of the effect of water on the lifetime of transducers, is to apply these equations to actual transducers for actual lifetime profiles. A computer program has been developed which will calculate (iteratively) the water concentration for a given transducer after a given exposure to moisture. This program will be applied to several transducers using a representative mission profile. The output for the program will be water content and electrical properties as a function of the submarine (or ship) lifetime. A special feature is a warning when water precipitation occurs (presuming that this would cause catastrophic failure if operated).

#### 2.4. PLANS

- Continue work on water permeation into sonar transducers and the effect this has on operation and lifetime (cooperative between Tasks A-1 and F-1).
- Complete research on TCP as a transducer fluid (Mar 1980).
- Perform testing on modified PTMG fluid (May 1980).

- Publish report containing detailed physical, chemical, and acoustic properties of a wide variety of transducer fluids.

### 3. TASK B-1 - CORONA ABATEMENT

*L. P. Browder - NRL-USRD*

#### 3.1. BACKGROUND

A significant percentage of transducer failures is due to voltage breakdown of insulating materials developing from corona erosion mechanisms. It is not practical to test the end item (transducer) to quantify the effects of corona erosion on transducer reliability and lifetime. Corona must be studied as a failure mechanism at the component or piece-part level to quantify the protection requirements and establish reliability factors. Transducer reliability may then be achieved by control of design parameters and construction processes.

#### 3.2. OBJECTIVES

The objectives of this task for FY80 are:

- A complete investigation of the lifetime function of PZT ceramic exposed to various levels of corona discharges in different gases and gas impurity mixtures.
- A formulation of the elementary transducer reliability function based on electrical breakdown considerations.

#### 3.3. PROGRESS

3.3.1. The PZT ceramic lifetime function for the continuous application of 60 Hz voltage was evaluated in nitrogen ( $N_2$ ) and perfluoropropane ( $C_3F_8$ ). A description of the test was given in the STRIP FY79 Fourth Quarter Progress Report [1]. Figure 3.1 is a duplicate of the figure used in the STRIP FY79 Fourth Quarter Progress Report but it includes the new data. The results show only a small margin of difference between  $C_2F_6$  and  $C_3F_8$  gases in this application.

The time-to-failure axis of Fig. 3.1 may be interpreted as the cumulative time of exposure to high voltage. To demonstrate this effect, several tests were stopped before failure occurred and a one hour rest given before the test was completed. In all cases, the cumulative time of voltage exposure for the interrupted tests were nearly the same as for uninterrupted tests.

Nitrogen gas did not yield a clear-cut lifetime function. On Fig. 3.1 the upper and lower limits for electrical failure are indicated. Some of the specimens endured 100 hours of testing at the upper voltage limit. The arcing event usually did not stay on

the PZT surface, instead it formed a channel through the gas. Pure nitrogen appears to be a poor choice for use as an insulator in sonar transducers, but there are indications that a mixture combination of this gas with other strong electronegative gases could be useful [2].

3.3.2. Factors of primary concern in this investigation of the PZT ceramic voltage lifetime function are those that affect the long-term voltage withstand capability. The results of studies of some of the factors are the following:

- Air and water vapor contamination of sulfur hexafluoride ( $\text{SF}_6$ ) gas have very little effect on the function for  $\text{SF}_6$  shown in Fig. 3.1. The limits of test were an air concentration fraction to 25% and water vapor to 3% (96% R.H.). Water vapor does cause a scattering of the data points as it did in air, resulting in an effective lowering of the curve but by only a few percent.
- Gas pressure changes with  $\text{SF}_6$  gas also had minimal effect on the function for  $\text{SF}_6$  shown in Fig. 3.1. The pressure levels of test were 50, 101, and 151 kPa. The breakdown voltage at a given time-to-failure increased about 3% for each 50 kPa pressure increment increase. This effect did not seem to be the result of corona which was much greater at 50 kPa than at 151 kPa.
- The effect on the lifetime function of changing the PZT ceramic thickness is shown in Fig. 3.2 for the gases  $\text{SF}_6$  and dry/wet air. Comparing Figs. 3.1 and 3.2 indicates that doubling the ceramic thickness also approximately doubles the failure voltage level, although there are some form difference between the curves for each gas.



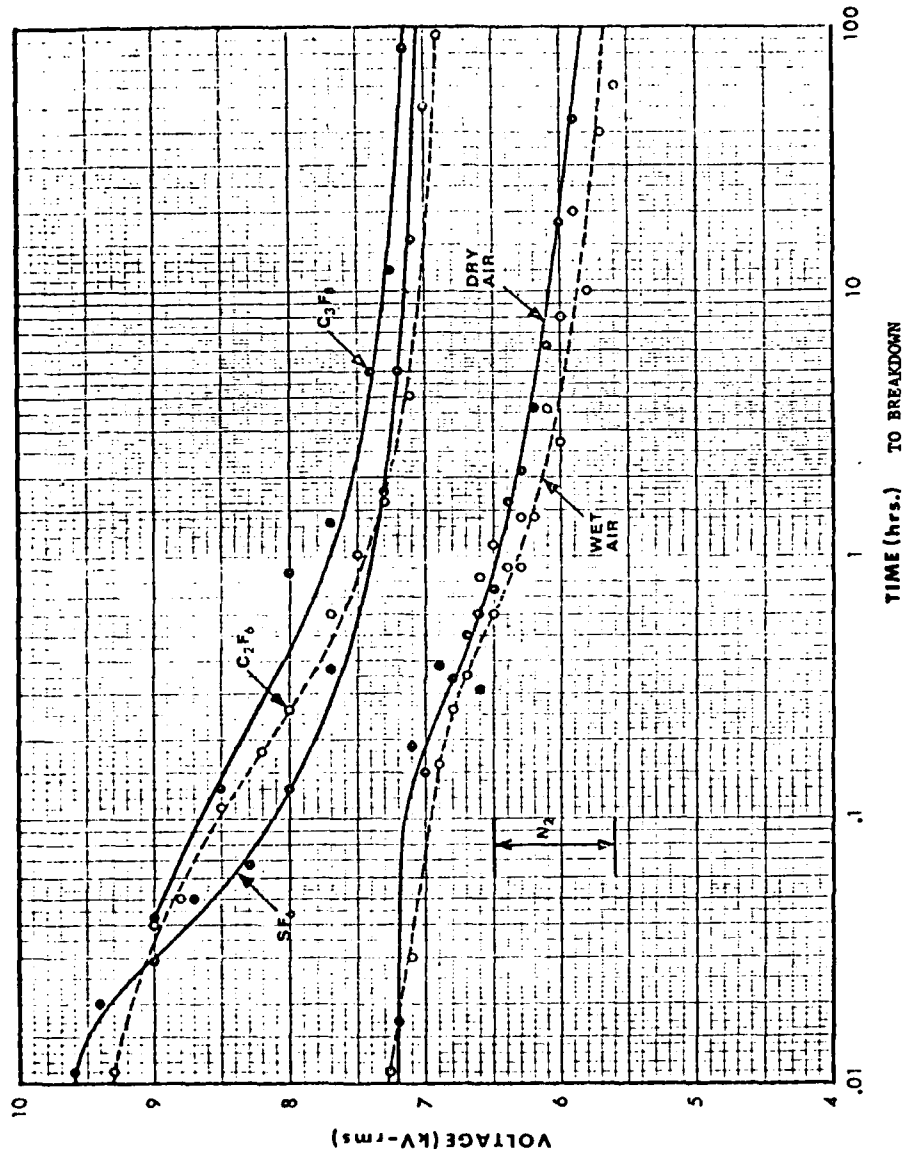


Fig. 3.1 - Voltage lifetime functions for 0.635-cm thickness PZT ceramic in various insulator gases

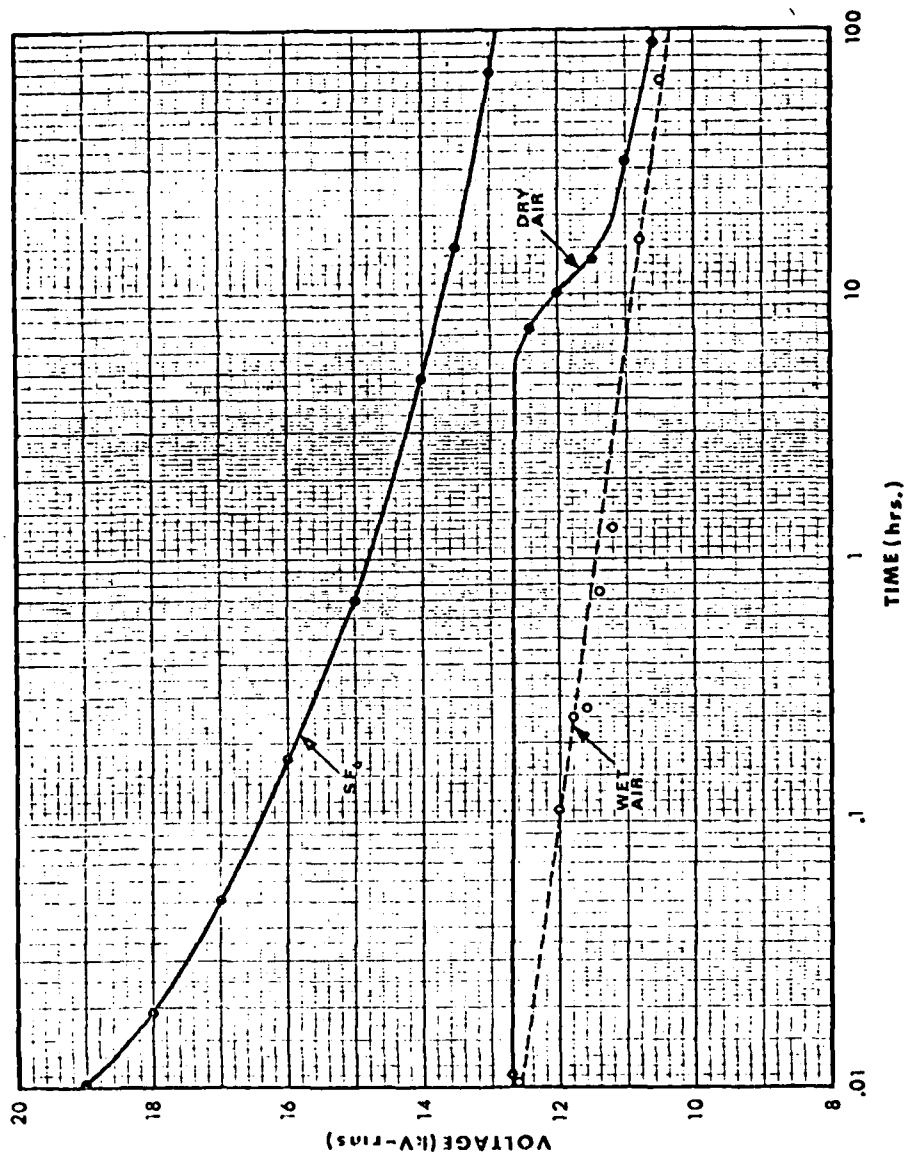


Fig. 3.2 - Voltage lifetime functions for 1.27-cm thickness PZT ceramic in air and SF<sub>6</sub> gases

3.3.3. The STRIP FY79 Fourth Quarter Progress Report [1] described a parasitic current flow to the test specimens which is not related to either corona or the usual capacitive component. An increase of the magnitude of this current has been directly correlated to the electrical failure of PZT ceramic.

Figure 3.3 is a line diagram for the test setup designed to give a direct real-time indication of this parasitic current flow. Equipment needed to complete the system is being procured. The test voltage supply and corona detector are parts of the Biddle Partial Discharge Test Equipment. The current transformer gives an output that is the difference between the capacitive currents in the test specimen and the high-voltage capacitor. When the capacitance of these two units are equal, the fundamental and higher frequency current components will cancel and leave the parasitic current waveform to be measured and evaluated.

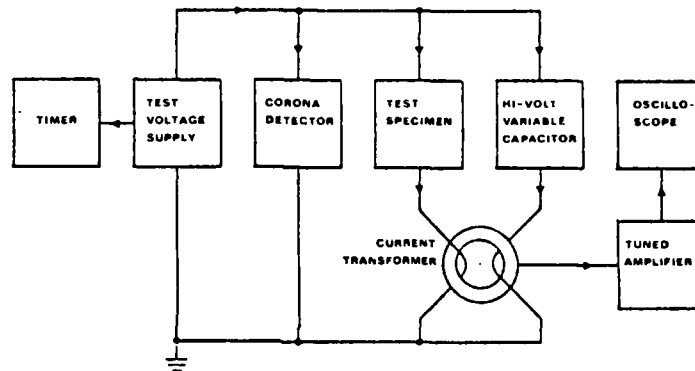


Fig. 3.3 - Test setup diagram for parasitic current flow detection

3.3.4. A report entitled "High-Voltage Endurance Function of the PZT Ceramic/Gas Insulator Interface in Underwater Sound Transducers" is being prepared for publication.

#### 3.4. PLANS

3.4.1. Tests will be conducted to evaluate PZT ceramic lifetime function and corona response due to unusual amounts of carbon dioxide, methane, and argon gases mixed in air.

3.4.2. Instrumentation will be assembled to investigate the parasitic current phenomena that leads to electrical failure of PZT ceramic.

#### 4. TASK C-1 - HANDBOOK FOR CONNECTOR AND CABLE HARNESS DESIGN

*G. D. Hugus - NRL-USRD*

##### 4.1. BACKGROUND

The selection of pressure-proof connectors and cable harnesses for hydrophones and transducers is a critical part of Navy shipboard sonar system design. Yet the design of these components for use in this environment is not covered in any one reference publication. Information on this subject is contained in a multitude of military and industry specifications, standards, and publications. The result is that engineers and designers often duplicate work and may overlook relevant information that they need.

##### 4.2. OBJECTIVE

The objective of this task is the preparation of a design handbook covering the technology of pressure-proof underwater connectors and cable harnesses for hydrophones and transducers. The emphasis will be on the application of these components for use in Naval surface ships and submarines.

##### 4.3. PROGRESS

Work to fulfill this objective will be performed under contract.

A preliminary list of contents of this handbook is as follows:

- Responsible NAVSEA Technical Agencies
- NAVSEA Approved Pressure-Proof Electrical Connectors
- NAVSEA Approved Outboard Cables
- NAVSEA Approved Cable Harnesses
- Preferred NAVSEA Pressure-Proof Connectors and Harnesses for Submarine Sonar Systems
- Pressure-Proof Electrical Connector Design
- Connector Receptacle Attachment Methods
- Outboard Cable Design
- Cable Harness Design
- Connector Termination Methods
- Cable Splicing - Repair Methods and Procedures
- Cable Harness Test Requirements
- Cable Harness Handling, Installation, Replacement and Testing

Quality Control Considerations

Typical Failure Modes and Effects Analysis (FMEA)  
for Connectors and Cable Harnesses

References

Bibliography

Appendix A - Glossary

Appendix B - Tables

Appendix C - PP Connector, Cable and Harness  
Supplier Listing

Appendix D - Listing of U.S. Personnel Involved  
in PP Connector and Harness Design and Use

#### 4.4. PLANS

Work in FY80 will be devoted to preparation and submission of the first draft of the handbook. Work will be started by the contractor during the FY80 Second Quarter.

## 5. TASK C-2 - STANDARD FOR O-RING INSTALLATION

*Dr. Colin J. Sandwith - APL, University of Washington*

*G. D. Hugus - NRL-USRD*

### 5.1. BACKGROUND

The reliability of sonar transducer arrays can be significantly improved by the adoption of standard procedures for the installation and assembly of O-ring seals. The problem is that no such standard procedure exists. Presently, the installation procedures are determined by the installer and the materials available at the time of installation.

The results of analyzing failures of O-ring seals in connectors used in underwater applications over decades show that roughly eight out of thirteen O-ring failures have resulted from improper installation and assembly or improper quality control and inspection procedures at the time of assembly. Stated another way, the results showed that even though O-ring seal design may be perfected by the proper O-ring type selection (piston, face, or crush), by the maximum crush section thickness, by selecting the proper O-ring size and material, and by using two O-rings in series (double O-rings) a substantial number of the O-ring seal failures will occur due to improper installation and inspection procedures.

### 5.2. OBJECTIVES

The objective is to compose, critique (by authorities), edit and present in final form a standard procedure for the installation of O-ring seals in electrical connectors and undersea static application. The standard will be composed in the form of similar military standards. Once the standard is approved by NRL and NAVSEA authorities it will be submitted for approval as a military standard.

### 5.3. PROGRESS

Work to fulfill this objective is being performed under contract N00024-78-C-6018 by the Applied Physics Laboratory of the University of Washington. The approach to developing this procedure will be to use all known proven techniques and procedures of users (military and commercial) and suppliers to develop a unified best procedure. The approach will be to collect from the literature, users and supplies all of the data and recommendations concerning each phase of the O-ring seal production. It will be itemized in the following manner:

- Acquisition
- Storage

- Inspection
- Cleaning
- Lubrication
- Assembly precautions
- Assembly tools
- Post-installation inspection
- Redundancy
- Followup observations and records

The standard will be composed and edited and sent to three authoritative and experienced personnel who are working in the area of seal technology for critiques. The critiques will be reviewed and considered in the final version of the standard. This version will be submitted to the STRIP program manager for review and recommendations. If acceptable, final submittal for approval as a military standard will be made to the proper agencies.

Progress includes completion of communication with the Military Standards representatives for recommendations on format. Partially complete is the collection of pertinent experience and data on O-ring failures, lubricants, procedures, and test methods; review of information in order to organize data; initiation of the first draft of the standard.

#### 5.4. PLANS

The first draft of the technical portion of the standard will be completed in the FY80 Second Quarter. Completion is also expected on the collection of information on O-ring failures, lubricants, procedures, and test methods.

## 6. TASK C-3 - CABLES AND CONNECTORS

*G. D. Hugus - NRL-USRD*

*D. E. Glowe - Texas Research Institute, Inc.*

### 6.1. BACKGROUND

The use of cables and connectors is an area of concern for long-term sonar reliability because of a history of failures. Deficiencies can be generally categorized in the four areas of: design of cables and terminations; specification and testing; handling; and repair and maintenance. Specific problems have been identified in a recent failure modes and effects analysis of cables and connectors prepared for NAVSEA by General Dynamics/Electric Boat. They conclude, that of all the problem areas, the loss of bond of the molded boot to the connector shell or to the cable sheath is the most probable cause of failure. Cable jacket puncture in handling, at installation or in service is considered to be the second most probable cause of failure.

### 6.2. OBJECTIVES

The general objective of the task is to provide improved reliability in the cables, connectors, and related hardware for the outboard elements of sonar transducer systems.

Specific objectives for the FY80 task area is to complete the following:

- Investigate the use of cable/connector boot clamps to determine reliability and failure modes.
- Investigate the strength of unshielded cable and the shielded cable to determine reliability and failure modes.

### 6.3. PROGRESS

6.3.1. Work to fulfill these objectives is being performed under contract N00173-79-C-0129 by Texas Research Institute, Inc. A task outline of this work was given in the STRIP FY79 Third Quarter Progress Report [3]. The progress, by task, is as follows:

- TASK 1: Develop Mission Profile and Test Plan  
The purpose of Task 1 is to produce quantitative data about the environment and conditions which cables experience during storage, installation, ship operations and maintenance, to design a test plan to adequately simulate those experiences, and to obtain sufficient cable to



evaluate the program. This task has been completed. The Mission Profile generated is given in the STRIP FY79 Fourth Quarter Progress Report [1].

• TASK 2: Comparative Testing of Cable

The test plan devised in Task 1 will be carried out with the testing of several cables commonly used in the fleet. They are:

<u>SHIELDED</u>	<u>UNSHIELDED</u>
DSS-2	DSU-2 (Two Types)
DSS-3	DSU-3
DSS-4	Trident 2-Conductor
FSS-2	Butyl 2-Conductor
	DSU-2 with reinforcement

The tests conducted on these cables were given in the STRIP FY79 Fourth Quarter Progress Report [1]. Work on this task is now complete. Results of cable component strengths are given in Table 6.1.

CABLE TYPE	COMPLETE CABLE		LESS JACKET		LESS JACKET & SHIELD		CONDUCTOR W/INSULATION		COMPONENT STRENGTH PSI	
	Force* lbs	Elong. %	Force* lbs	Elong. %	Force* lbs	Elong. %	Force* lbs	Elong. %	Jacket	Belt
DSS-2 (unshielded)	117	46	N/A	N/A	N/A	N/A	52	7	1600	N/A
DSS-2	138	76	128	47	104	56	46	7	1300	850
DSU-2	113	50	N/A	N/A	N/A	N/A	47	7	1900	870
DSS-3 (#1)	256	70	223	48	161	46	78	19	1200	880
DSS-3 (#2)	253	77	227	68	164	38	78	19	1300	970
DSU-3	193	56	153	30	N/A	N/A	83	16	1800	2400
DSS-4	347	84	335	56	271	54	133	16	1100	1200
FSS-2	297	57	278	51	203	36	52	15	920	1300
Butyl	172	73	165	64	N/A	N/A	78	13	1600	1500
Trident	180	49	N/A	N/A	N/A	N/A	64	12	N/A	N/A

\*Tensile force when the first component failure was observed.

Table 6.1 - Cable Component Properties

- TASK 3: Analysis of Results

Results of the tests conducted in Task 2 were examined to determine relative abilities of shielded and unshielded cables to survive the Mission Profile. Work on this task is complete and the results will be presented in the final report. Preliminary analysis reveals that failures during the breaking bend tests, where the samples were pulled 180° around a 5.1 cm diameter, were not significantly different than those during the tensile breaking strength tests. The cable capacitance during breaking strength tests did not show a rapid change before cable failure. Therefore, capacitance monitoring would not predict cable failure. The test for shielded vs unshielded cable performance during pressure cycling in a packing gland type hull penetrator showed continual movement of the unshielded cable through the penetrator during each pressure cycle. This would cause cable failure due to the excessive strain caused by cable movements through the gland.

The second concurrent phase of this project is to investigate the use of cable/connector boot clamps to determine reliability and failure modes. This phase is composed of five tasks.

- TASK 4: Develop Mission Profile and List Candidate Clamps

The purposes of this task are to produce a quantitative estimate of the Mission Profile of the connector, and a complete list of candidate clamping systems which may be selected for the tests. The Mission Profiles from this and Task 1 have been combined and were given in the STRIP FY79 Third Quarter Progress Report [3]. This task is complete. The three candidate clamps chosen were Oetiker preformed clamps, Band-It preformed clamps, and Band-It Scru-Loct retrofittable clamps.

- TASK 5: Manufacture Instrumented Connectors

Under this task, TRI is manufacturing a quantity of MIL-C-24231 (Portsmouth) connectors

which have been modified to permit instrumentation. The instrumentation will allow immediate determination of the presence of a leak and identification of the leakage paths. Sixty-four instrumented connectors for Tasks 6 and 7 have been manufactured.

• TASK 6: Conduct Factorial Experiment

The 32 instrumented connectors manufactured for this task were subjected to the test cycle given in Table 6.2. Cycles 3 and 5 were omitted in testing connectors 17 to 32 because these cycles did not appear to cause failures, and also to speed up completion of this task. Table 6.3 shows the leakage path resistances measured after completion of the test cycle. Table 6.4 summarizes the failure analysis performed on the connectors with low resistance.

CYCLE	DESCRIPTION
1	No presoak - pressure cycle* only
2	7 day soak @ 25°C - pressure cycle*
3	7 day soak @ 25°C - pressure cycle*
4	60 hrs. soak @ 60°C - pressure cycle*
5	-110°C, 160 hrs. @ 71°C dry - pressure cycle*
6	60 hrs. soak @ 70°C - pressure cycle*
7	24 hrs. soak @ 88°C - pressure cycle*

\* 0-100 psi hold for 5 min.  
repeat for 3 cycles  
0-2000 psi hold for 2 hrs.

Table 6.2 - Test Cycle Description

NO.	TYPE	PATH	Resistance Reading*						
			CYCLE 1	CYCLE 2	CYCLE 3	CYCLE 4	CYCLE 5	CYCLE 6	CYCLE 7
1	DSU-3	PU-G	---	---	---	1G	---	6G	26
2	Clamp	PU-U	2G	2.5M	(Flooded "O" ring)	2M	X	X	X
3		N-G	---	---	---	1G	---	9G	1.5G
4		N-U	100M	800M	1G	1.5G	2G	2G	1G
5	DSU-3	PU-G	---	---	---	1.5G	---	---	---
6		PU-U	---	2G	600K	1G	---	800M	300M
7		N-G	1G	(Flooded "O" ring)	Cont	1G	2G	2G	300M
8		N-U	2M	300M	---	1.5G	---	---	1.5G
9	DSU-3	PU-G	3G	1G	1G	1.5G	---	2G	200M
10		PU-U	---	1.5G	3G	1M	Cont	100K	X
11		N-G	---	2G	---	X	Cont	X	X
12		N-U	300M	500M	Cont	300M	2G	1.5G	900M
13	DSU-3	PU-G	---	400M	---	1.5G	---	---	1.5G
14		PU-U	---	---	---	1G	X	X	X
15		N-G	700M	600K	2M	150K	1G	1G	1G
16		N-U	4G	5G	5G	800M	5G	3G	3G

\* --- = Resistance Greater than 10 Gigaohm C = Cable  
 G = Gigaohm B = Back shell  
 M = Megaohm X = Removed from test  
 K = Kiloohm Cont = Continuity measured

PU = Polyurethane  
 N = Neoprene  
 G = Bonded  
 U = Unbonded

Table 6.3 - Factorial Matrix Summary



Connector No.	Type	Analysis	Action
2	PU-U DSS-3 No Clamp	Cable bond failure, cycle 3	Removal from test after cycle 4
6	PU-U DSU-3 No Clamp	Cable bond failure during cycle 3	Clamp added to boot over cable
18	PU-U DSU-3 PRE-FORM	Boot cracked under clamp after cycle 6	Removed from test after cycle 6
10	PU-U DSS-3 OETIKER	Cable bond failure, under gap in clamp	Remove from test after cycle 5
11	N-G DSS-3 OETIKER	"O" ring leakage was not recognized and connector prematurely dissected	Removed from test after cycle 3
14	PU-U DSU-3 OETIKER	Cable bond failure during 4th cycle	Removed from test after 4th cycle
25	PU-G DSS-3 SCRU-LOKT	Cable shorted, apparently mechan- ically, no leakage noted	Removed after 4th cycle, returned to test after failure analysis
26	PU-U DSS-3 SCRU-LOKT	Cable bond failure	Removed from test @ 5th cycle
29	PU-G DSU-3 SCRU-LOKT	Lack of bond on back shell and cable, leak- age on both interfaces	Removed from test after 7th cycle

Table 6.4 - Low Resistance Connector Analysis

- TASK 7: Conduct Accelerated Life Tests on Connectors

A set of 32 instrumented control connectors manufactured under Task 5 will be subjected to accelerated life testing (ALT). The control connectors will be polyurethane, bonded onto the shielded cable with no clamps. Since initial results of Task 6 indicate that the neoprene boot outperforms polyurethane, the remaining connectors (32) will be made with neoprene. A final ALT plan is being designed based on analysis of the Task 6 data.

- TASK 8: Analysis of the Test Results

The results of the two tests (Factorial Experiment and Connector ALT) will be examined to provide answers to the questions about reliability and failure modes of boot clamps and to organize the additional data for useful presentation. This analysis will be presented in the final report.

Analyses of the resistance readings from Task 6 (Table 6.3) show several interesting trends. First, the two neoprene unbonded, unclamped connectors (Numbers 4 & 8) have not failed. The resistance readings have in fact increased with progressive aging and after seven cycles the readings are comparable to bonded connectors. This may be a result of elastomer compression due to water swelling. Second, polyurethane connectors have failed at the cable interface. Clamping the boot to the cable seems to help (connector No. 6) but does not prevent failure. Third, clamp type does not appear to influence clamp performance at the cable bond.

6.3.2. A standard procedure was submitted for evaluation to STRIP covering the fabrication of neoprene Portsmouth connector plugs for submarine outboard cables. This was a first draft written at NUSC/NLL. It was evaluated and a critique was sent to the writer based on USRD's experience in molding neoprene.

#### 6.4. PLANS

Work will be complete by the end of next quarter. Documentation will be in the form of an NRL Report written by Texas Research Institute, Inc. A paper will also be presented at the Marine Technology Society meeting on cables and connectors in March 1980.



## 7. TASK D-1 - ALTERNATIVE MATERIALS: PLASTICS

*D. E. Moore, NWSC*

### 7.1. BACKGROUND

It has become apparent that there is a need to replace certain structural materials on sonar transducers because, in some instances, acoustic reflection, cost, availability, or corrosion have created serious problems. When repairing, modifying or designing sonar transducers these parameters must be considered and in many instances plastic would be an excellent alternative material.

Until recently, plastics have been in limited use with the exception of thermoset polyesters with glass or Kevlar fiber mesh added for support and strength. This particular type of plastic is not reusable and cannot be formed to precise dimensional tolerances. Therefore, it has very limited usefulness to the field of sonar transducers. Thermoplastics, which are a more recent development, are reusable, low in cost, and can be injection molded to precision tolerances. Glass fiber can be added for high strength and in most cases any shrinkage or expansion is isotropic and minimal.

At this time, very little technical information exists for exposure of thermoplastics in sea water. In order to determine whether injection molded thermoplastics can in fact be used as an alternative material, it will be necessary to test and evaluate different types of plastics.

### 7.2. OBJECTIVES

The objective of this task is to prove the reliability and determine the applications of plastics in an ocean environment.

### 7.3. PROGRESS

This is a new task for FY80. The approach to the objective will include the following steps:

- Perform a two-year equivalent accelerated life test (ALT) on 8 types of thermoplastic materials immersed continuously in substitute ocean water (ASTM D1141).
- Immerse 8 types of thermoplastics in an ocean environment with approximate constant temperature for two years.

- Evaluate test specimens of both aging environments for changes of shear and tensile strength, volume, weight (water absorption) and acoustic impedance.
- Compare the data for the two environments to determine both the aging characteristics and the validity of a 10-20 year equivalent accelerated life test for plastics use as sonar transducer structural materials.

A literature search has begun for existing information in this field. NRL Memorandum Report 4097 [4] contains a discussion of the diffusion equations and of the acceleration of the tests. Also included are results of salt and fresh water exposure of several elastomers and plastics over a range of temperatures. NRL Technical Report No. 7447 [5] contains numerous literature references to ocean testing of materials. Only a few pertinent high-strength laminates are referenced. The testing done was apparently restricted to ocean submersion.

A number of excellent candidate materials are available for consideration. These are listed below with preliminary comments about their advantages.

- Polycarbonate, 40% glass-filled - dimensionally stable in molding, widely used, "good" water resistance.
- Polysulfone, 30% glass-filled - an amorphous material (i.e., very tough with moderate tensile strength), good to excellent dimensional stability, very good for resistance to salt water.
- Polyphenylene sulfide, 40% glass-filled - a crystalline material (i.e., not extremely tough but reinforces well), extremely strong but somewhat brittle, "good" water resistance but degrades in sunlight.
- Nylon 6/10, 40% glass-filled - highest strength in reinforced state of any nylon; highest flexural modulus of any considered plastic; slight expansion on molding, very low moisture uptake.

- High-strength nylon (Zytel), 40% glass filled - good impact strength.
- Amorphous nylon, 40% glass-filled - good strength, very tough, good chemical resistance, dimensionally stable.
- PBT Polyester, 40% glass-filled - crystalline, extremely low moisture absorption, fair strength and toughness.
- Polyphenylene oxide/Styrene (Noryl), 30% glass-filled - very low moisture absorption, good thermal properties, high impact strength, "good" flexural modulus and tensile strength.

Some of these 8 materials will be chosen and acquired for the testing program. The tests to be performed to evaluate the aging characteristics are as follows:

- Tensile strength - (ASTM D638)
- Shear strength - (ASTM D732)
- Water absorption - (ASTM D370)
- Volumetric change
- Sound speed - time of flight velocimeter

The temperatures that will be used to evaluate the acceleration of the test are: 10, 25, 50, and 75°C. Ocean tests will be run for each material in parallel with the laboratory tests. The ocean exposure will be at the NRL Corrosion Test Lab in Key West, FL. Coordination of this testing has been with Dr. Millard Peterson of NRL. Dr. Bogar of the Corrosion Test Lab will remove the samples at the appropriate time interval and ship them to NWSC.

If the ocean tests do not contradict the results of the laboratory accelerated test (for example, by biodegradation) it will be possible to determine the properties of plastics after expected shipboard lifetimes.

#### 7.4. PLANS

- Fabricate support bracket for specimens to be used at ocean test site.

- Obtain the thermoplastic test specimens and begin testing in both environments.
- Test and evaluate the 8 materials at the specified intervals.
- Determine the activation energy of the two environments, the usefulness of the plastics and the validity of this type of ALT.

## 8. TASK D-2 - MATERIALS EVALUATION

*C. LeBlanc - NUSC*

*C. M. Thompson - NRL-USRD*

### 8.1 BACKGROUND

Pressure release materials are used to mechanically and/or acoustically isolate some components of sonar transducers to improve overall acoustic performance. Normally the pressure release materials must operate effectively under bias stress anywhere from 0.3 MPa (50 psi) to 20 MPa (3 kpsi) over a discrete temperature range, e.g., 5°C to 40°C. To predict performance it is essential to know the properties of the materials under the imposed constraints. Previous measurement methods for determining the properties of some pressure release materials, such as Sonite (an asbestos - glass fiber composite), onion-skin paper, syntactic foams, Hytrel (a thermoplastic polyester elastomer), etc., have given relative results with a hydraulic press or bulk effects with an impedance tube. There is a strong need to correlate existing measurement data and to establish a standard measurement system to be used by the Navy for incorporation into specifications and/or acceptance tests on pressure release materials.

An additional problem is that pressure release materials absorb the transducer fill-fluids. This process increases the acoustic impedance of the pressure release material and thus reduces the effectiveness of its acoustic insulation. Degradations of from 3 dB in 3 years to 6 dB in 10 years have been reported in transducers in the field, and attributed to changes in the pressure-release material.

There are thus two phases to this task: the material characterization phase and the fluid absorption phase.

### 8.2. OBJECTIVES

The objectives of this task are:

- To initiate and evaluate a standard dynamic measurement system to determine the properties of pressure release materials over the ranges of stress from 50 psi to 3 kpsi and at temperature from 5 to 40°C.
- To measure and evaluate candidate pressure release materials, such as Sonite, onion-skin, corprene, etc.

- To quantify the changes in acoustic properties of cork-rubber composites as they absorb transducer fill-fluids.
- To test a transducer element for changes in sensitivity as a function of castor oil content of its pressure release material.
- To develop a method that will predict changes in the acoustic properties of cork-rubber composites with time (and in turn predict changes in transducer directivity and sensitivity).
- To identify the specific problems with DC-100 which may eventually lead to its replacement with a more suitable material.

### 8.3. PROGRESS

8.3.1. The math modeling was continued for the dynamic measurement system, which has been described in a previous quarterly progress report. The driver unit, consisting of a longitudinal stack of fiberglass-wrapped (prestressed) Type III ceramic rings with head and tail masses plus stress rod, was completely disassembled to obtain precise dimensional information needed as input for the math model computer program developed by the Raytheon Company for this task area. The math model will be implemented in the second quarter of FY80. The driver unit is now completely reassembled and ready for use.

The static measurement system, developed to augment the dynamic measurement data, appears to be working satisfactorily. However, a problem exists in defining initial conditions on some of the pressure release materials under consideration; e.g., "What constitutes valid equilibrium conditions on soft materials in terms of prestress and prestress cycles?" In other words, data on virgin material can be substantially different from data at equivalent stress levels after the material has been stressed and stress cycled.

8.3.2. The USRD G-19 calibrator is a standing wave device used to calibrate small hydrophones by comparing the voltage response of the unknown hydrophone with that of a standard hydrophone. In this quarter, the G-19 calibrator was primarily used to compare the differences in the voltage response of a PZT-4 ceramic disc wrapped with various pressure release materials to that of a F61 standard transducer.

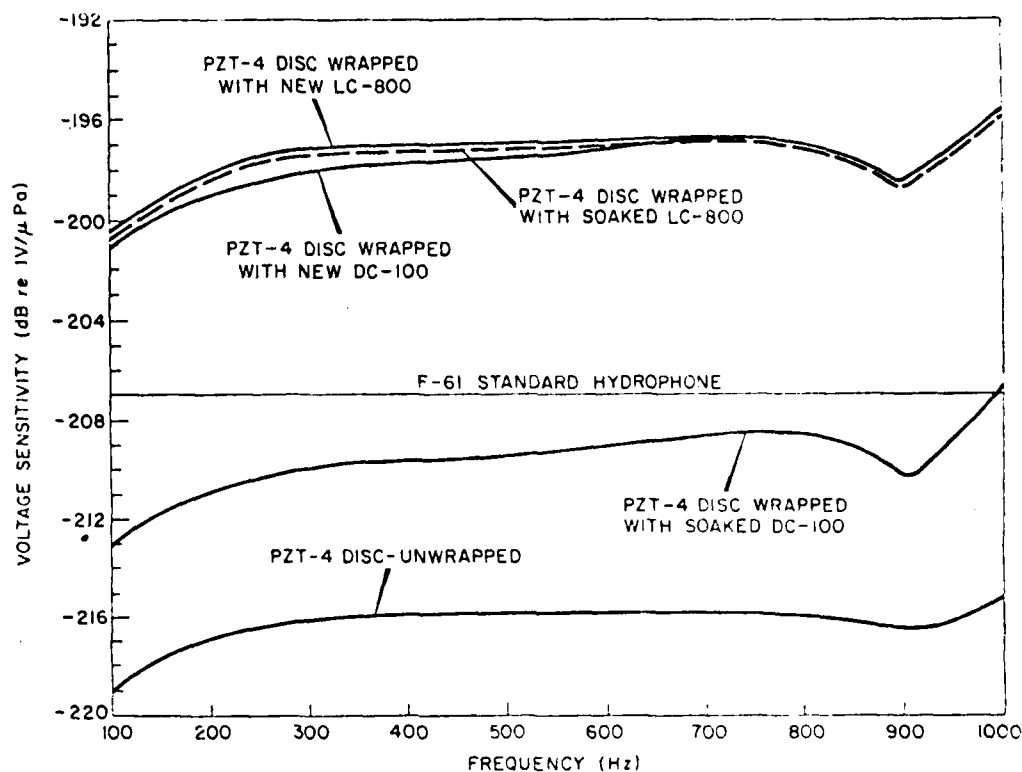


Fig. 8.1 - Comparison of the degradation in sensitivity caused by soaking LC-800 and DC-100 cork-rubber composites.

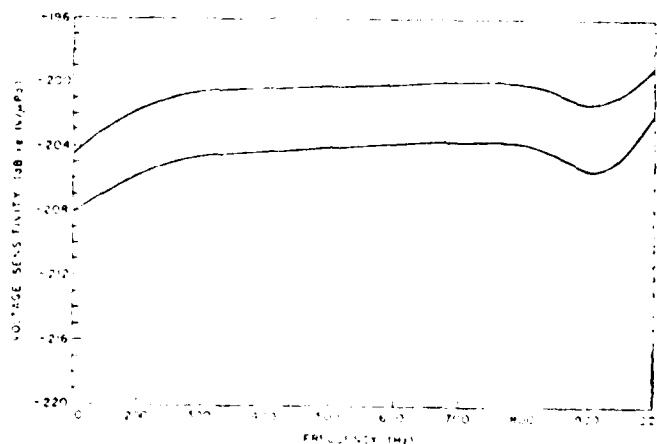


Fig. 8.2 - Sensitivity of a PZT-4 ceramic disc hydrophone wrapped with oil-soaked and unsoaked NC-775 composite.

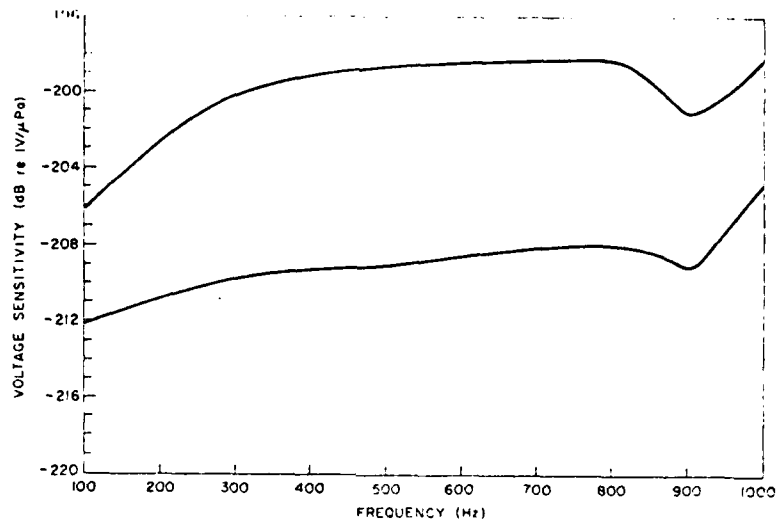


Fig. 8.3 - Sensitivity of a PZT-4 ceramic disc hydrophone wrapped with oil-soaked and unsoaked DC-116 composite.

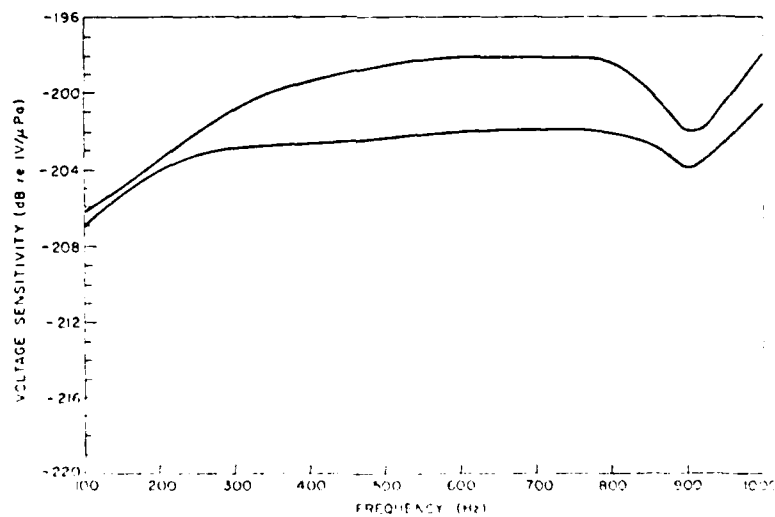


Fig. 8.4 - Sensitivity of a PZT-4 ceramic disc hydrophone wrapped with oil-soaked and unsoaked NC-710 composite.



The various pressure release materials shielded the PZT-4 disc radially and were held in place by an aluminum split ring and collar. The G-19 calibrator was filled with Fluorinert FC-75, a liquid dielectric, to approximately one centimeter from the top. The test hydrophone was lowered into the calibrator using nylon tire cord tied to a ring stand on one end and cemented to the aluminum collar on the other. This configuration afforded very precise positioning of the hydrophone element for the series of calibrator tests. The only parameters varied throughout the test series were the pressure release materials and the projector frequency, which was varied from 100 Hz to 1000 Hz in increments of 100 Hz.

A number of configurations and cork-rubber compositions were used for shielding the PZT-4 element. In some cases, rings were die cut from the various materials (both dry and castor oil-saturated) and stacked around the element. In this way, oil soaking from the ends could be simulated by replacing dry rings with oil-soaked rings. In other cases, a thin layer of material was wrapped radially around the element thus simulating oil soaking from the radial direction.

The results shown in Fig. 8.1 through 8.4 and in Table 8.1 are from tests in which the PZT-4 disc was radially wrapped with DC-100, DC-116, NC-710, NC-775, or LC-800 of 0.318-cm thickness, then replaced by another piece of the same material that had been exposed to castor oil at 75°C for one year. Figure 8.1 shows the relationship between the sensitivity of an unshielded PZT-4 element and the same element wrapped with soaked and unsoaked DC-100 (cork-neoprene) and with soaked and unsoaked LC-800 (cork-silicone). (Sensitivity of the F61 standard is shown for comparison.) Examination of the curves shows that the sensitivity of the element wrapped with new LC-800 is greater than when wrapped with new DC-100. Additionally, the sensitivity degrades much less when wrapped with soaked LC-800 than with soaked DC-100. These results might have been anticipated from the impedance tube work previously reported [1]. From this work, DC-100 is seen to almost double in sound speed (at 0 MPa) on being soaked in castor oil. LC-800 composite changes by only 25% on being soaked in castor oil under the same conditions. Figures 8.2 through 8.4 show the sensitivities of PZT-4 discs wrapped with soaked and new NC-775 (cork-nitrile rubber composite), DC-116, and NC-710. Table 8.1 gives a synopsis of these results. Here it is seen that the loss of sensitivity upon soaking is roughly related to the amount of castor oil absorbed by the material.

CORK-RUBBER MATERIAL	% INCREASE IN WEIGHT	LOSS OF SENSITIVITY (dB)
DC-116	68	9.9
DC-100	65	11.5
NC-710	50	4.1
NC-775	13	3.7
LC-800	9	0.2

Table 8.1 - Percentage increase in weight and loss of sensitivity (at 700 Hz) for 5 cork-rubber composites exposed to castor oil at 75°C.

The conclusion at this point is that the common choice of DC-100 as a pressure release material for sonar transducers may be far from the best one. LC-800 is slightly superior when new and may be vastly superior as the transducer ages. Other cork-rubber composites are also seen to degrade less than DC-100.

#### 8.4. PLANS

- Prepare final report on cork-rubber-soaking phase of this work (Feb 1980).
- Measure static and dynamic properties of pressure-release materials at ambient temperature (Jul 1980).
- Investigate frequency dependence of pressure release materials (Jul 1980).
- Collect information and prepare final report on the measurement of properties of pressure-release materials (Sep 1980).

9. TASK E-1 - STANDARDIZED TEST PROCEDURES  
*J. Wong and D. Carson - NOSC*

9.1. BACKGROUND

It is at present not possible to subject a transducer specimen to a series of environmental stresses over a short time period and prove, if it passes certain operating parameter tests, that the specimen is a reliable transducer with a certain minimum expected life in fleet use. Of course, if we could simply use a set of transducers for the desired fleet life, we could check the failure rates against acceptable replacement or repair rates. But the approach here is to accelerate the environmental stress actions, and thereby subject the transducer specimen to seven years of life cycle stresses in a few weeks or months.

9.2. OBJECTIVES

The objective of this task is to develop a set of standardized procedures to accelerate the aging of transducers based upon environmental stress requirements.

9.3. PROGRESS

The first equivalent one year stress exposures under the Composite Unit Accelerated Life Test (CUALT) plan for the two Hazeltine Corporation DT-605 hydrophones (S/N A1 and S/N A5) was completed near the end of the last quarter. These two hydrophones were formerly identified as DT-308, S/N A1 and S/N A5, but the nomenclature has been changed to DT-605. Table 9.1 shows the CUALT procedures for one equivalent year of stress for both the DT-605 hydrophone and the TR-316 projector. Acoustic (receive sensitivity, input impedance magnitude and vertical beam patterns) and insulation DC resistance measurements indicated that no significant deterioration in the performance of the two hydrophones after the first equivalent year of CUALT.

Figures 9.1a and 9.1b show the receive sensitivities of the two narrow-beam and the two wide-beam staves, respectively, for the S/N A5 hydrophone. These figures compared the receive sensitivities measured before the start of CUALT with those measured after the 475 hours of 75°C dry heat exposure and after the completion of one equivalent year of CUALT. Each of the four beam staves output was terminated with a 50-ohm resistor at the end of a 100-foot 2SWF4 test cable as required in the Critical Item Procurement Specification (CIPS). Both narrow-beam staves, staves 1 and 2, still meet the specification at the center-band frequency  $F_0$  and the total variation in sensitivity across the operating frequency band

Exposure	Time	Purpose	Time Compression	Equivalent Service
1 Dry Heat 75° C UV Exposure*	475 Hours	Accelerate rubber degradation, reaction between fill fluid & components, mechanical stress on boot due to expansion, degradation of rubber, simulate dockside storage.	Accelerated aging	16,300 hrs at 70°F (E=13,000) 1-2 hrs/day of sunlight for 9 mo.
2 Fresh Water 60°C*	TEST: 40 hrs	BEAM PATTERN, TVR, OIL PRESSURE, RUBBER CHANGES, MEGGER Water permeation, simulate wet operation	Duty Cycle increase Accelerated Aging	575 hrs at 20°C(E=13,000) 18,750 hrs at 20°C (E=30,000) 1 year diving
3 Pressure Cycling	TEST: 250 cycles	Mechanical stress, water intrusion, water permeation, simulate diving conditions MEGGER, ACOUSTIC PROBE	Duty cycle increase	32 hrs at Pressure
Pressure Dwell, 600 psi	2 X 16 hrs	ea Mechanical stress, water intrusion, water permeation, simulate diving conditions	Duty cycle increase	
4 Thermal Shock -54° to 0°C	3 cycles	Mechanical stress due to contraction elastomer and adhesive integrity, water intrusion, simulate, arctic conditions.	Duty Cycle increase	One Arctic mission
5 Repeat Pressure Cycling & Dwells	Same as Exposure No. 3			
	TEST: BEAM PATTERNS, TVR, IMPEDANCE			
6 High Power Drive *	168 hrs	Simulate continuous operation	Duty Cycle increase, stress increase	One Arctic mission

\*UV, Fresh Water 60°C and High Power Drive exposures are eliminated for the DT-605 hydrophone.

Table 9.1 - Composite Unit Accelerated Life Test (CUALT) Simulating One Equivalent Year of Stress for TR-316 ( ) or DT-605\* (Revised July 1978)

Figure 9.1a. Receive Sensitivities of Hazeltine DT-605 Hydrophone During First Year of Composite Unit Accelerated Life Test (QUALT)

S/N A5 (formerly DT-308, S/N A5) Hydrophone outputs terminated with 50 ohms resistors at end of 100 ft. of 25M74 test cable

Legend:

- O - Before start of QUALT
- - After 477 hrs. of 75°C Dry Heat Stress Exposure
- X - End of First Equivalent to One Year of Stress Exposures

Stave 1, IBD (Narrow Beam Section)

Stave 2, IBD (Narrow Beam Section)

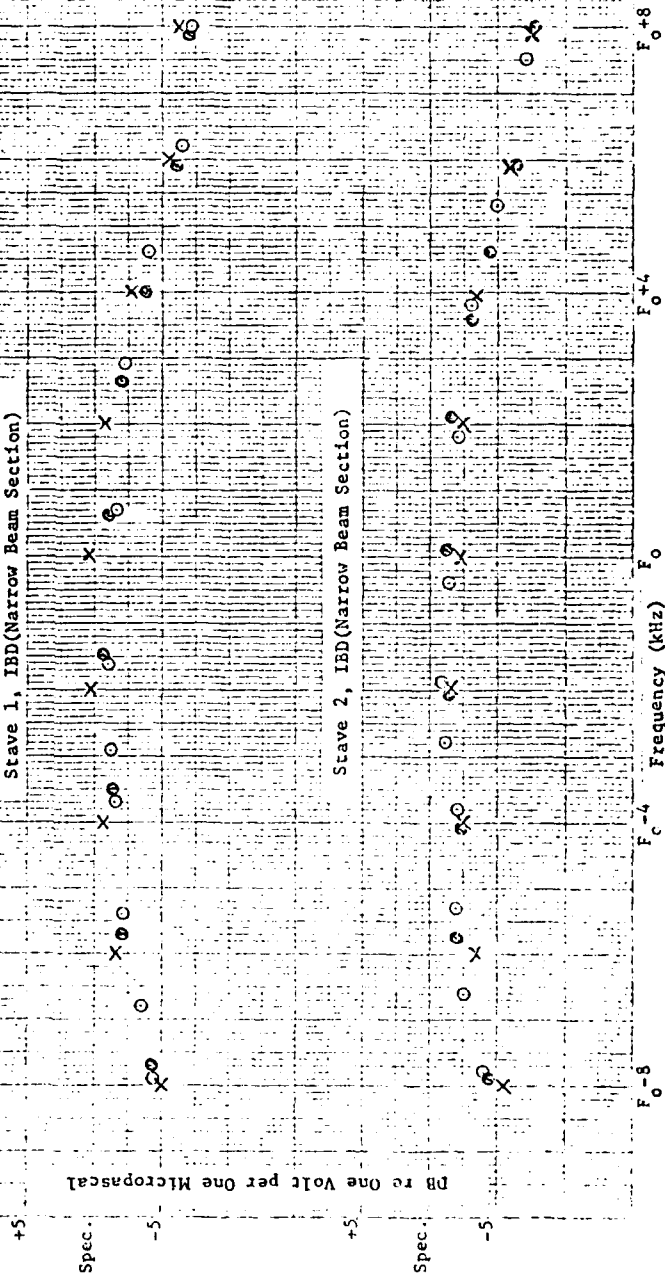
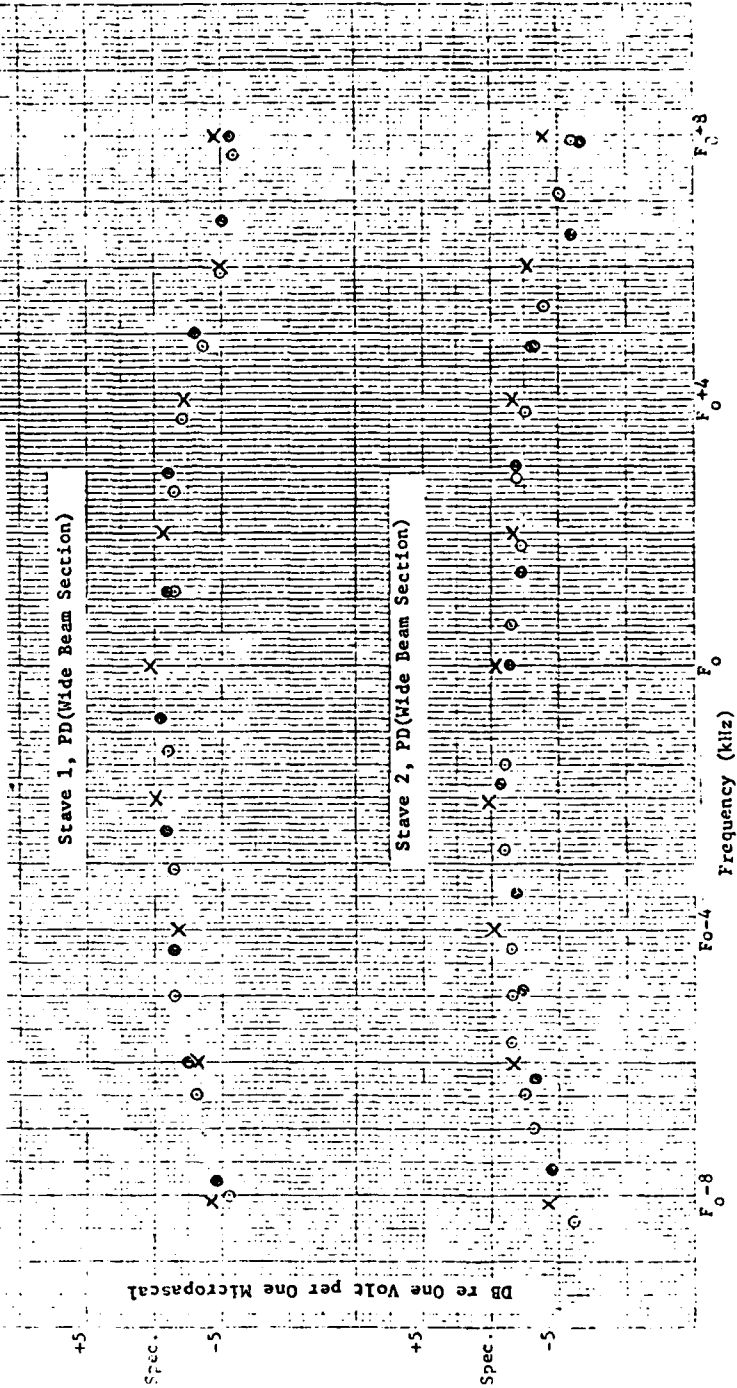


Figure 9.lb. Receive Sensitivities of Hazeltine DT-605 Hydrophone During First Year of Composite Unit Accelerated Life Test (QUALT)

S/N A5 (formerly DT-308, S/N A5) Hydrophone outputs terminated with 50 ohms resistors at end of 100 ft. of 25MF4 test cable

Legend:

- O - Before start of QUALT
- - After 477 hrs. of 75°C Dry Heat Stress Exposure
- X - End of First Equivalent to One Year of Stress Exposures



of  $F_0 \pm 5$  kHz. Similarly, the two wide-beam staves receive sensitivities are within the specification across the same operating frequency band.

Figures 9.2a and 9.2b are the receive sensitivity plots for S/N A1 hydrophone. The receive sensitivities for this unit were measured with the cable outputs open-circuited, not terminated with 50-ohm resistance as required in the CIPS, prior to the start of the first year CUALT. This was not discovered until the two hydrophones had already been subjected to the first year CUALT. Therefore, only the receive sensitivities measured after the 75°C dry heat exposure and at the completion of the first year CUALT are compared. The two narrow-beam staves (Fig. 9.2a) are within specification as described for unit S/N A5. The results of the two wide-beam staves (Fig. 9.2b) indicated that the sensitivities measured at the end of the first year CUALT still meet specification. These last measurements were rechecked and found to be accurate. Note, however, that the sensitivities after the first sequence of CUALT (75°C dry heat exposure) are approximately 2 to 3 dB lower from specification. This is the only beam section of the two units that shows inconsistency. It should be mentioned that the wide-beam sensitivities of this unit (S/N A1) after the dry heat exposure were not measured on the same day as the narrow beam, but eight days later. It is possible that the later measurements may be in error by approximately 2 to 3 dB. If there is a real variation or deterioration in the sensitivities of the wide-beam staves of S/N A1 unit, the second year CUALT may reveal it.

The second year CUALT on the DT-605 was initiated in October 1979 and has completed the 75°C dry heat exposure. However, because funds for the FY80 CUALT project have not yet been received by NOSC all tests relating to CUALT have been temporarily discontinued.

#### 9.4. PLANS

9.4.1. Continue with the accelerated life test on the two Hazeltine Corporation DT-605 hydrophones.

9.4.2. Initiate accelerated life test on the Ametek/Straza TR-316 projectors when projectors become available.

9.4.3. Make necessary revision of CUALT plan to improve speed and cost-effectiveness of achieving more year equivalents of DT-605 and TR-316 stress exposures.

9.4.4. Start development of CUALT procedure for the SQS-56 transducers.

Figure 9.2a. Receive Sensitivities of Hazeltine DT-605 Hydrophone During First Year of Composite Unit Accelerated Life Test (QUALT)

S/N A1 (formerly DT-308, S/N A1) Hydrophone outputs terminated with 50 ohms resistors at end of 100 ft. of 25K74 test cable

Legend:

- O - Before start of QUALT
- - After 477 hrs. of 73°C Dry Heat Stress Exposure
- X - End of First Equivalent to One Year of Stress Exposures

Stave 1, IBD(Narrow Beam Section)

Stave 2, IBD(Narrow Beam Section)

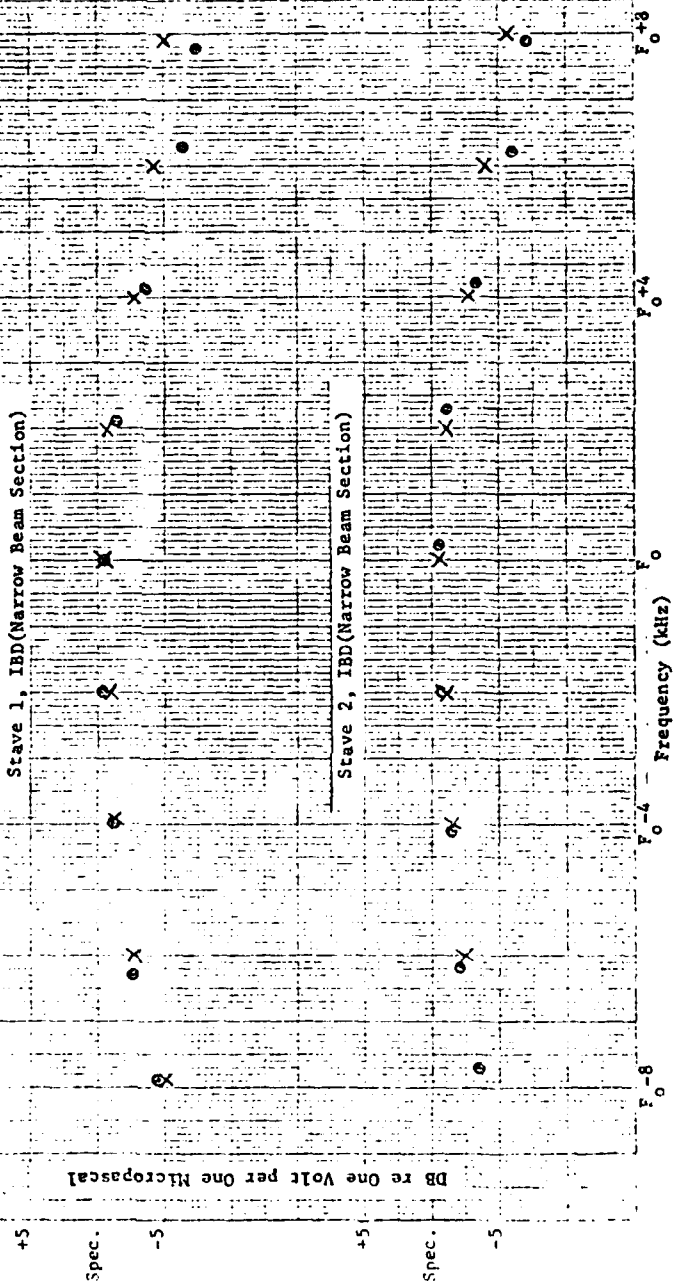




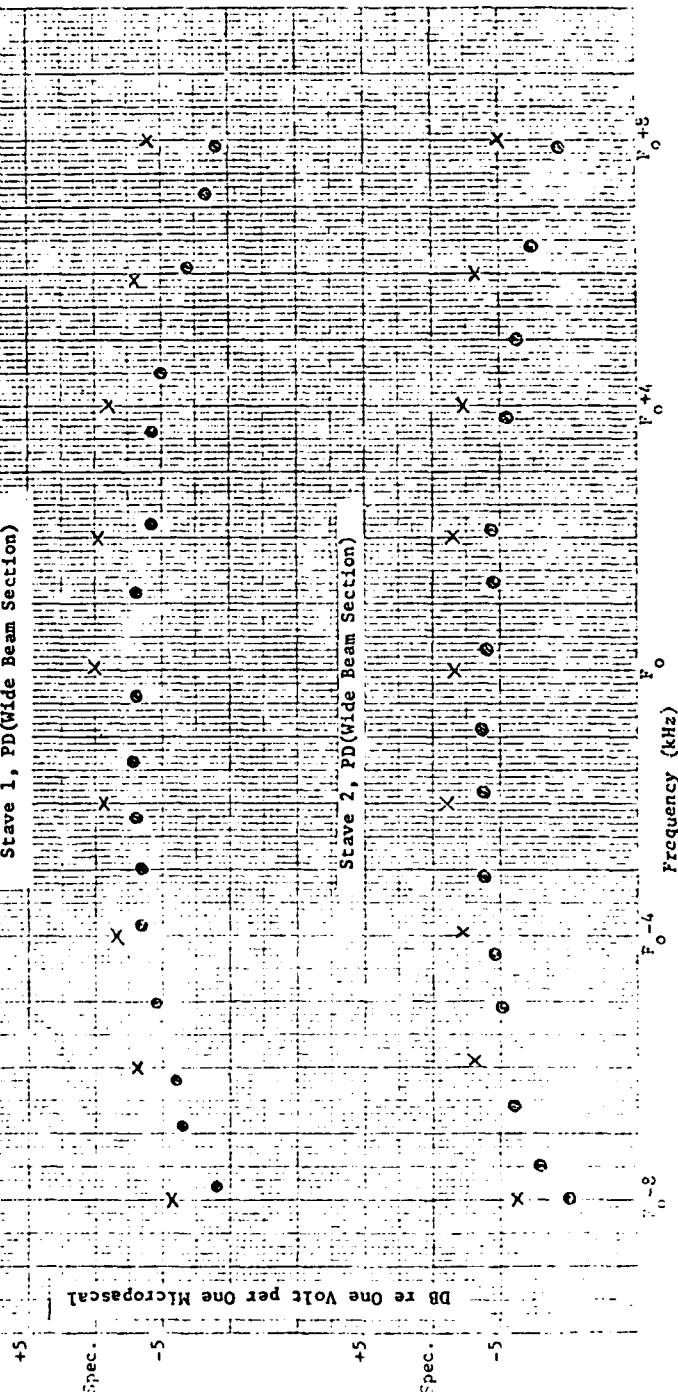
Figure 9.2b. Receive Sensitivities of Hazeltine DT-605 Hydrophone During First Year of Composite Unit Accelerated Life Test (QUALT)

S/N A1 (formerly DT-308, S/N A1) Hydrophone outputs terminated with 50 ohms resistors at end of 100 ft. of 25W4 test cable

Legend:

- - Before start of QUALT
- - After 477 hrs. of 75°C Dry Heat Stress Exposure
- X - End of First Equivalent to One Year of Stress Exposures

Stave 1, PD(Wide Beam Section)



## 10. TASK E-2 - ACCELERATED LIFE TEST VERIFICATION

*D. E. Moore - NWSC*

### 10.1. BACKGROUND

Composite Unit Accelerated Life Testing (CUALT) is becoming an accepted procedure for determining the production reliability and expected service period of sonar transducers. At this time no attempt has been made to determine the accuracy and validity of the CUALT concept. One approach for verifying this method is comparing the aging results of post-service transducers with those of transducers that have been exposed to the CUALT procedure.

This type of technique has proven very useful in determining the acceptability of data obtained from performing Accelerated Life Tests (ALT) on materials. Many times it was determined that ALT was effective only for specific materials or environments and this could be true for certain transducers when performing CUALT.

### 10.2. OBJECTIVES

The objective of this task is to verify the accuracy of the ALT concept by comparing results with a known real-time life test.

### 10.3. PROGRESS

This is a new task for FY80. The approach to the objective contains the following steps:

- Test and evaluate post-service DT-168B hydrophones to determine the aging characteristics.
- Disassemble post-service DT-168B hydrophones that have been removed from a specific submarine and determine the original production drawing package.
- Build new hydrophone units according to the drawing package.
- Develop a CUALT Mission Profile for the DT-168B.
- Perform CUALT on the new DT-168B hydrophones.
- Compare the data of both the post-service and CUALT hydrophones to determine the test method reliability.

During the first quarter, work was concentrated on the first two items with the following results. An entire array of DT-168B hydrophones was removed from the SSBN-634 (USS Stonewall Jackson) in August 1978. The hydrophones from this array were manufactured between March and August 1972 and have been selected as the test specimens to be used in this task. The array was shipped to NUSC/NLL. Mr. Jan Wilczynski performed reciprocity tests on this array and this information is being made available to the Naval Weapons Support Center (NAWPN SUPPCEN) Crane. Of the 48 hydrophones, two were removed for analysis by Mr. Hector Cini and the remaining 46 were shipped to NAWPN SUPPCEN Crane for use in this project. Visual inspection and null balance testing has been performed on 47 units and one was impossible to test because of leaking castor oil. Seven hydrophones did not pass null balance and at this time it has been ascertained that these failures were caused by curvature of the cage. Impedance, cable resistance, capacitance, and dissipation were tested on all units and met the required electrical specifications. The DT-168B hydrophones were disassembled in order to determine both the aging characteristics of specific sub-assemblies (e.g. rubber boot) and the exact assembly drawing revisions used in production of these specific hydrophones.

A letter has been sent requesting access to the "steaming schedule" of the SSBN-634. When permission is granted, it will be possible to record the pressures, temperatures, and drying cycles that the hydrophones were exposed to. A Mission Profile (procedure) can be developed for the CUALT from this information.

#### 10.4. PLANS

- Develop an accurate assembly drawing package.
- Test and evaluate the post-service hydrophones for aging characteristics.
- Build 10 DT-168B hydrophone units according to the original assembly (1972).
- Obtain submarine "steaming schedule" data.
- Develop a CUALT procedure.
- Perform CUALT on the 10 new hydrophones.
- Test and evaluate the hydrophones after CUALT.
- Compare the test data with that of post-service hydrophones for determination of CUALT reliability and effectiveness.

11. TASK F-2 - TEST AND EVALUATION: SHOCK HARDENED PRESSURE RELEASE  
*C. J. Wilson, Westinghouse*

11.1. BACKGROUND

A study recently completed by Westinghouse addressed the use of polyimide and glass-loaded polyester materials as a pressure release mechanism in the TR-155F transducer. Transducers using these pressure release materials in place of the "standard" Belleville springs were subjected to extraneous noise and acoustic tests. While the test results were encouraging, the pressure release configurations were not intended to withstand the rigors of explosive shock.

11.2. OBJECTIVES

The objectives of this task are to develop, test, and evaluate the effectiveness of polyimide and polyester-elastomer-glass as a shock hardened pressure release material.

11.3. PROGRESS

This is a new task for FY80. The approach to the objectives will be to assemble, test, and evaluate 14 transducers incorporating "shock hardened" configurations of the polyimide and 20% glass-loaded polyester pressure release materials. Modified transducers will be tested and evaluated on the basis of acoustic performance, extraneous noise performance, and resistance to explosive shock. Complete documentation of the modified transducers, including cost analysis of the proposed changes, parts list, assembly procedure, engineering and assembly drawings, analysis modeling, test results, and photographs will be included.

The glass-loaded polyester and polyimide materials have been received and the necessary parts fabricated. The static stiffness of the polyester pressure release configuration was measured on twelve samples and ranged from  $2.645 \times 10^7$  N/m to  $3.328 \times 10^7$  N/m which compares favorably with the data obtained in the earlier study. The static stiffness of one polyimide sample has been measured at  $2.89 \times 10^7$  N/m.

The 14 government-furnished equipment transducers have not been received which is holding up further progress.

11.4. PLANS

When the transducers are received they will be modified with the new pressure release configurations, subjected to tests at Westinghouse and then scheduled at the various facilities for acoustics, noise, and shock tests.

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DISTRIBUTION LIST  
for  
Sonar Transducer Reliability Improvement Program  
(STRIP)

Commanding Officer  
Naval Coastal Systems Center  
Panama City, FL 32407  
ATTN: Code 750A, R.L. Cook  
Code 753, R. Lovejoy  
Code 790, D.F. Folds

Officer-in-Charge  
Civil Engineering Laboratory  
Naval Construction Battalion Center  
Port Hueneme, CA 93043  
ATTN: Code L43, J.V. Wilson

Commander  
Naval Electronic Systems Command  
Washington, DC 20360  
ATTN: Code 320, Ms. J. Bertrand

Commander  
Naval Ocean Systems Center  
271 Catalina Blvd  
San Diego, CA 92152  
ATTN: Code 712, D.L. Carson  
Code 712, J. Kinnison  
Code 7122, J. Wong  
Code 7122, Dr. R.R. Smith  
Code 7123, C. Bohman  
Code 724, Dr. G.E. Martin

Commanding Officer  
Naval Research Laboratory  
Washington, DC 20375  
ATTN: Code 2628 (20)  
Code 2628 (12 for DDC)  
Code 5000

Transducer Repair Facility  
Mare Island Naval Shipyard  
Vallejo, CA 94592  
ATTN: C. Porterfield  
F. Peglow

Transducer Repair Facility  
Pearl Harbor Naval Shipyard  
Pearl Harbor, HI 96860  
ATTN: Code 270.3, R. Shigeta

Transducer Repair Facility  
Portsmouth Naval Shipyard  
Portsmouth, NH 02804  
ATTN: Code 216.11, A. Theirrien  
Code 267.73, W.W. Lovell

Commander  
Naval Sea Systems Command  
Washington, DC 20362  
ATTN: SEA06H5-21, Ms. D.G. Bagley  
SEA63R-12, C.C. Walker  
SEA63XT, R.E. Heaney  
SEA63XT-1, C.A. Clark (3)  
SEA63XT-2, P. Greenhaus  
SEA63XT-4, T.G. Martin  
SEA05N/6107B4D, J. Pratchios  
SEA05H, S. Blazek

Commanding Officer  
Naval Weapons Support Center  
Crane, IN 47522  
ATTN: Code 70553, D.J. Steele  
Code 70553, D. Moore

Commanding Officer  
Naval Underwater Systems Center  
New London Laboratory  
New London, CT 06320  
ATTN: Code 316, Dr. C.H. Sherman  
Code 316, T. Mapes  
Code 316, R. DeAngelis  
Code 316, R. Vogelsong  
Code 316, C. LeBlanc  
Code 316, C. Olds

Superintendent  
Underwater Sound Reference  
Detachment  
Naval Research Laboratory  
P.O. Box 8337  
Orlando, FL 32856  
ATTN: Code 5900  
Code 5970  
Code 5975 (5)  
Code 5977 (4)  
Code 5978  
Code 5930  
Code 5915.2 (5)

Ametek Straza  
790 Greenfield  
El Cajon, CA 92022  
ATTN: H. Lewis  
E. Barnes  
R. Simmons

Applied Physics Laboratory  
University of Washington  
1013 NE 40th  
Seattle, WA 98105  
ATTN: Dr. C.J. Sandwith

General Dynamics  
Electric Boat Division  
Groton, CT 06340  
ATTN: E.C. Hobaica  
R. Haworth

Hazeltine Corporation  
115 Baystate Drive  
Braintree, MA 02184  
ATTN: G.W. Renner

Man Tech Corporation  
Century Bldg, Suite 103  
2341 Jefferson Davis Highway  
Arlington, VA 22202  
ATTN: S.S. Shimomura

Sperry Gyroscope Division  
Division of Sperry Rand Corp.  
Marcus Avenue  
Great Neck, NY 11020  
ATTN: G. Rand, MS D-18

Submarine Signal Division  
Raytheon Co.  
P.O. Box 360  
Portsmouth, RI 02871  
ATTN: N. Serotta, K<sub>33</sub> Transducer  
Program Manager  
D. Ricketts, Consultant,  
Design Engineering Lab

Texas Research Institute, Inc.  
5902 W. Bee Caves Road  
Austin, TX 78746  
ATTN: Dr. J.S. Thornton (2)

Department of Civil Engineering  
University of Utah  
Salt Lake City, UT 84112  
ATTN: Dr. B. Hufferd

MAR, Inc.  
1335 Rockville Pike  
Rockville, MD 20852  
ATTN: Dr. W. Cramer

TRACOR, Inc.  
Systems Technology Division  
1601 Research Blvd.  
Rockville, MD 20850  
ATTN: P. Flannery  
B. McTaggart  
J. Guarnieri  
J. McClung

Honeywell, Inc.  
Marine Systems Center  
5303 Shilshole Avenue, NW  
Seattle, WA 98107  
ATTN: C. Sheets

Potomac Research  
P.O. Box KK  
McLean, VA 22101  
ATTN: P. Watson

Harris Inst. Corp.  
33 Southwest Park  
Westwood, MA 02090  
ATTN: A. Poturnicki